THE ROCKFORD (ILL.) TYPHOID EPIDEMIC.*

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The city of Rockford is situated on Rock River in the northern part of the state of Illinois. The population is estimated at about 50,000 (1900, 31,051; 1910, 45,401). In January and February, 1912, a sudden outbreak of typhoid fever occurred, involving about 200 bed cases. The writers were requested by the city authorities on February 14 to investigate and report on the cause of the epidemic.[1]

Record-cards were prepared, and first-hand data were obtained in the case of every patient of whom it was possible to learn. At the time of our inquiry typhoid fever was not a reportable disease in Rockford, but through the active co-operation of the Rockford physicians and with the assistance of the city authorities and the daily press, what is believed to be a very complete list of the actual bed cases was soon obtained. We were fortunate, through the courtesy of Dr. D. W. Day of the department of hygiene of the public schools, in securing the services of several very efficient school nurses for collecting the data regarding the typhoid fever cases. The knowledge of local conditions thus placed at our disposal greatly facilitated the investigation.

In all, a record of 199 cases occurring between January 23 and February 29, 1912, was obtained. In 177 of these cases definite information was secured regarding absence from the city prior to the outbreak. Of this number 173 had not been away from Rockford for at least 30 days prior to the onset of their illness. The cases comprised 102 males and 97 females. The age distribution is as follows:

Years		Years	
0– 5	13	31–45	28
6–15	46	45+	18
16–30	88	Not noted	6

* Received for publication May 21, 1912.

[1] We were ably assisted in our investigation by Mr. A. H. Hixson.

The approximate date of the earliest symptoms was determined in 187 cases. Where exact information could not be obtained, the date of the physician's first visit could generally be ascertained with accuracy. Hill's experience[1] has shown that in the neighboring state of Minnesota seven days probably represents the average interval between the physician's first visit and the earliest symptoms, and our own experience tends to confirm this view. Tabulating the results in three-day periods according to this method the following table is obtained:

January 23–25..... 1	February 7– 9..... 31	February 21–23..... 1
January 26–28..... 5	February 10–12..... 24	February 24–26..... 1
January 29–31..... 26	February 13–15..... 15	March 1–28..... 9
February 1– 3..... 41	February 16–18..... 6	
February 4– 6..... 37	February 18–20..... 1	

The date of appearance of the earliest symptoms places the date of typhoid infection for the majority of the cases in the week following January 16. As will appear presently, this coincides exactly with the other facts bearing on the origin of the epidemic.

The dates of "taking to bed" seem to give a less precise indication of the probable date of infection. Arranged in similar three-day periods, the dates of taking to bed are as follows:

January 23–25..... 1	February 7– 9..... 30	February 21–23..... 12
January 26–28..... 1	February 10–12..... 28	February 24–26..... 1
January 29–31..... 1	February 13–15..... 37	March 1–28..... 11
February 1– 3..... 15	February 16–18..... 13	
February 4– 6..... 22	February 18–20..... 18	

In a number of cases the record-cards show that the doctor was called before the patient had gone to bed, in others that the patient had been in bed for a week or more before summoning a physician. An aid to fixing the precise date of infection is the important circumstance, to be discussed presently, that the typhoid epidemic was ushered in by an outbreak of diarrhea which affected over 70 per cent of all those who afterwards developed typhoid fever. It is perhaps partly owing to this diarrheal outbreak that there was a large proportion of typhoid patients who kept their feet for a considerable time after first feeling ill, attributing their symptoms to

[1] "The Mankato Typhoid Fever Epidemic," *Jour. Infect. Dis.*, 1911, 9, p. 435.

the after-effects of the "intestinal grip" from which they had previously suffered. In many individual instances of which we learned there was a history of "intestinal grip January 16–18; patient has not been well since." It therefore seemed probable that in the Rockford outbreak the date of onset was more accurately placed by the method of dating back seven days from the physician's first visit than by the method of reckoning from the date of taking to bed.

There were in all 24 deaths from typhoid fever[1] attributable to the outbreak, two deaths occurring in January (January 6 and 27) not being included in our tabulation. Placing the date of infection in the week following January 16, the deaths occurred in the following order:

Third week after the initial infection	3	deaths.
Fourth " " " " "	4	"
Fifth " " " " "	5	"
Sixth " " " " "	6	"
Seventh " " " " "	3	"
Eighth " " " " "	1	"
Ninth " " " " "	1	"
Eleventh " " " " "	1	"

The deaths distributed according to age and sex are as follows:

Sex	Age	Cases	Deaths	Percentage
Males	0–19	33	1	3.1
Females	0–19	47	6	13.0
Males	20+	69	9	13.0
Females	20+	50	7	14.0
	Not known	..	1	....
Total		199	24	12.1

While the numbers dealt with are too small to have by themselves much statistical value, the results are of interest from their substantial agreement with the grouping observed by Hill in the similarly caused Mankato epidemic,[2] save that the proportion of female deaths under 20 years was much smaller in his series. The discrepancy between the male adult and the male child case mortality in Rockford is as marked as in the series reported by Hill (11.1 per cent males 20+; 3.6 per cent males 0–19).

[1] Two deaths occurring before February 1 were attributed to the "gastro-intestinal grip."

[2] Loc. cit.

PRIMARY AND SECONDARY CASES.

Owing to the fact that the period of infection probably extended over at least several days, it is impossible in the present outbreak to make a perfectly sharp distinction between primary and secondary cases. There were in all:

170	1-case families
13	2-case "
1	3-case family

In four of the 2-case families the second case developed 15–20 days after the first case and late in the outbreak (February 16, February 17, February 22, and March 13, respectively). These four cases are probably to be regarded as secondary infections due to contact. Early in the outbreak measures were taken to guard against the spread of infection. With the co-operation of the newspapers and city health authorities wide publicity was given to dangers of transmission of infection from existing cases and to the necessary precautions to be observed. Nurses, physicians, and those in close attendance on the sick very generally received anti-typhoid vaccination, and the intercourse between sick and well was reduced to a minimum. It is perhaps partly due to such measures as well as to the absence of fly infection and other hot-weather influences that the rather sudden cessation of the epidemic was due. Whatever the explanation, the number of secondary cases seemed to be less than usual. Only 11 cases developed in the month of March; three of these had suffered from enteritis January 16–20.

In an explosive outbreak of typhoid fever occurring in winter, fly-borne infection and contact infection may be excluded as possible causes. The information obtained by our house-to-house canvass likewise excluded milk-supply as a primary factor. As many as 49 different milk dealers supplied the families in which typhoid fever had developed and in no instance was the number of cases on any particular milk-route disproportionate to the number of customers on that route.

Many circumstances pointed to the city water supply as the source of infection. Although about one-twentieth of the population is said to use water from private wells, many of which are

obviously badly placed, there was no evidence that these wells were responsible for the outbreak. On the contrary the users of well water were notably freer from disease than the users of city water. Several instances came to our notice of families using private wells, all the members of which were exempt save those that drank city water at school or at their places of business. In every one of the 178 cases of typhoid fever regarding which information could be obtained the city water was used constantly or occasionally.

The events preceding the outbreak of typhoid fever were indicative of water infection. On January 16–20 there had been a severe and sudden outbreak of gastro-enteritis or epidemic diarrhea. This was explosive in character and bore all the marks of a general water infection. On January 19, one of the Rockford morning papers printed a column and a half under the caption "Epidemic of Intestinal Grip Sweeps Rockford," in the course of which the statement was made that "*The* * was told last night [January 18] by doctors that they have been kept busy night and day for two days past and there is no apparent let-up." This is the first published statement we have been able to find and seems to fix the beginning of the outbreak on January 16–17. This conclusion was confirmed by the results of an intensive investigation made by us to which reference will be made presently.

The epidemic of enteritis was widespread and affected persons of every age and social station. Although no part of the city was free from the disease, certain districts suffered more severely than others. A probable reason for the unequal distribution of cases will appear later.

The proportion affected in factories with and without private wells was particularly significant. In three large factories employing about 1,150 persons we obtained on inquiry a history of 77 who had been attacked by enteritis; in another group of six factories situated in the same district as the foregoing there was a history of 433 attacks in an employed population of 617. The sole discoverable difference was that the first group of factories had private deep wells (5.8 per cent of force attacked by enteritis), while the second group of factories was supplied only with city water (70.2 per cent attacked by enteritis). Since many of those

employed in the factories lived in homes supplied with city water it is to be expected that there would be some cases among the employees of the relatively exempt factories.

The incidence of the enteritis upon the users of city water is shown also by the following among a large number of similar instances collected by us.

1. Family A., 5 members, all drinking well water at home: C. A., 9 years old, attending B school, where he drank city water, was attacked with enteritis; none of others affected. T. A., head of family employed at N. factory where 80 per cent suffered from enteritis. T. A. never drank much at factory and after first cases appeared carried water from home.

2. Family O., living outside city limits and using own well. M. O. worked at N. factory and drank water there: he was affected; his wife W. O. was in Rockford on January 19 and developed enteritis; the other members of the family, three in number, were not affected. All the members of two neighboring families, none of whom were in the city January 16–20, remained well.

3. Family K., eight members, city water; M. K., head of family, employed in factory with private well, never drank water at home. All members of family except M. K. sick with enteritis.

Such instances showed conclusively the connection between the city water supply and the outbreak of gastro-enteritis. Indeed the season of year at which the epidemic occurred, its explosive nature, its general distribution, the number of persons affected, and its general resemblance to similar outbreaks elsewhere traced to water-borne infection pointed unmistakably in this direction, even before the exact facts were ascertained.

There were all grades of severity exhibited in the cases, from exceedingly virulent choleraic symptoms to a slight indisposition, with mild diarrhea. Two persons are said to have died as the direct result of the enteritis. Many mild cases on the other hand never came under a physician's care. We were fortunate in securing a satisfactory basis for an approximate estimation of the number of cases. At our request the school nurses visited all public schools, and, by consulting the records of absence and interviewing the children with the co-operation of the teachers of the various grade

rooms, were able to obtain a reasonably accurate list of all school children that suffered from enteritis on January 16–20. In the case of some of the youngest children definite information could not be obtained, so that the actual number of cases of illness of which we obtained record is unquestionably somewhat below the truth. In a school enrolment of 6,303 at the time of the outbreak we learned definitely of at least 1,357 cases of enteritis. Inquiry from physicians and others showed that school children had not suffered disproportionately to the other age-groups of the Rockford population. If we assume that the same ratio of attack holds for all ages as for the school population, then there were not less than one-fifth, or about 10,000 of the total population, affected.

Some estimates of local observers are much higher than this. One of the daily papers on January 19 declares that "The universality of the disease is apparent in the fact that nearly every business institution has its victims from two to a score or more, and almost every block and every house has some member suffering from an intestinal difficulty." Some factories were forced to shut down on account of the large number of employees affected. "Public schools were decimated" on January 19. "Superintendent P. R. Wallace found this morning that every school had a large number of pupils on the absent list." One writer in a morning paper (February 13) asserts that "probably three out of four people in Rockford were affected" by the "intestinal grip" epidemic.

An intensive investigation of a limited area was made by us of one block in South Rockford (bounded by Main, Church, Morgan, and Loomis Streets). Of the 46 persons resident in this block, 40 suffered from gastro-intestinal disturbance. These were all users of the city water and drank of it during the period January 16–20. Of the six remaining persons one later developed typhoid fever and two drank no city water or drank it only in small amounts. The earliest date of onset (where the dates could be exactly stated) was the evening and night of January 16, when four individuals became ill. These were followed by five on January 17, five on January 18, one on January 19. Twenty-two could not recall the exact day of illness. The usual symptoms were nausea, vomiting, and diarrhea, followed by extreme prostration. Fever was

rarely present. Abdominal pain and tenderness were present in some cases. In some instances, diarrhea was the only symptom, and in two nausea and vomiting without diarrhea. Recurrences of the enteritis at intervals of three to four days were noted in nine cases.

It is thus clear that two extensive outbreaks of disease occurred in Rockford in January and February, 1912, one a more or less violent gastro-enteritis with a short period of incubation, the other a typical epidemic of typhoid fever following the gastro-enteritis after about two weeks. As is well known, similar outbreaks in Mankato, Minn., and other localities have been traced to water infection. All indications, therefore, pointed to an infection of the public water supply on or about January 16.

It is important to consider here the prevalence of typhoid fever in Rockford prior to 1912. The following table gives the record of deaths so far as obtainable.

	1906	1907	1908	1909	1910	1911	1912
January	..	1	0	0	1	0	2
February	..	0	0	0	0	0	6
March	..	0	0	0	1	0	15
April	..	0	0	0	0	0	2
May	..	1	0	0	0	2	..
June	..	1	0	0	0	3	..
July	..	0	0	0	3	0	..
August	..	0	0	0	0	0	..
September	..	0	1	0	4	1	..
October	..	0	3	0	0	0	..
November	..	0	0	2	0	0	..
December	..	0	0	0	1	2	..
Total	1	3	4	2	10	8	..

Unfortunately, typhoid fever cases have not been generally reported in Rockford and the number of deaths is too small to warrant any general conclusions. At the same time the fact is worth noting that there were as many deaths from typhoid fever reported in 1910 as in the four years, 1906–9 together. So, too, is the fact that the 1910 death-rate from typhoid fever in Rockford was over 22, a rate so high as to be ordinarily associated with a more or less polluted water supply. We have further gained the impression in conversations with Rockford physicians that scattered cases of enteritis or "intestinal grip" have been more common in Rockford in recent years than is quite normal for a community

with a water supply that is absolutely uncontaminated at all times.

On the other hand, a number of careful analyses of the city water made by the State Water Survey under the direction of Professor Bartow at various times both before and after the diarrheal outbreak invariably showed a water of great purity. If contamination had occurred, therefore, it must have been occasional, not continuous.

WATER SUPPLY.

The following description of the water supply is taken in part from personal inspection, in part from a special "Report on the Enlargement and Extension of the Water Supply and Distribution System of the City of Rockford, Ill.," made by Messrs. Alvord, Maury, and Mead in November, 1910.

The original waterworks system was constructed in 1874–75, when the population of the city was about 12,000. It is stated that the present site was selected because of the occurrence there of excellent springs. "The spring supply was developed by laying tile drains through the gravel in the immediate vicinity of the pumping station, and to a so-called filter well. Above the tile drains, where they entered the filter chamber, were placed coke, gravel, and stone, and the water entering the tile flowed to the well, and, passing upward through the filtering material into the filter chamber and then to the pumping pit, was finally taken by the pumps. A pipe also connected the upper portion of the filter well with the river, so that the river water might be admitted on emergency. The actual flow of the original springs is unknown, nor is there any record of the capacity of the springs when developed as above described."

Some years later the filter well was pronounced inadequate to supply the demand for water and a new well 38 feet in depth was sunk south of the pumping station which drew its supply from the extensive sand and gravel deposits in that section of the city. "Throughout this period the river water was frequently admitted into the mains for fire purposes." In 1885 analysis of the well water was said to show that it was inferior in quality to the river

water and the well was hence abandoned, and only river water used. The need of a different supply was soon recognized, and the first artesian well was sunk to the Potsdam sandstone to a depth of 1,530 feet. Additional wells were drilled in the years immediately following.

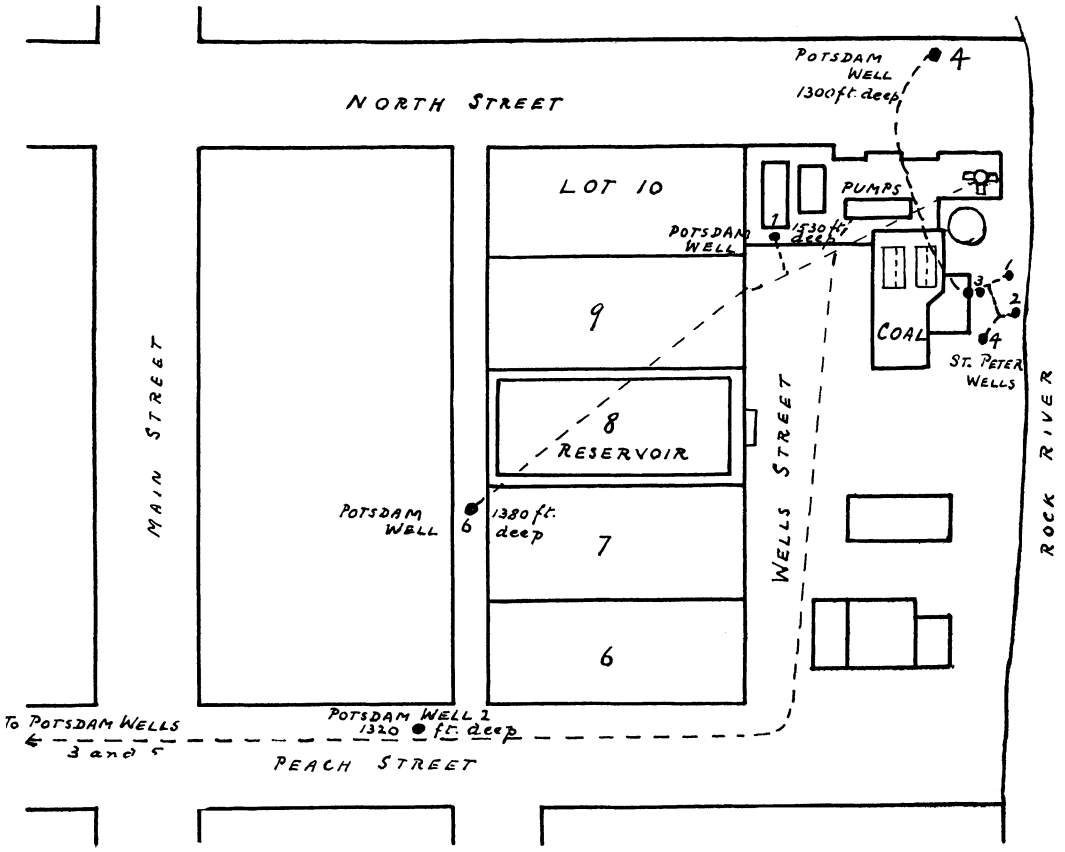


FIG. 1.—Rockford pumping station and surroundings.

At present the water supply of Rockford is obtained from a group of eleven wells, five to the St. Peter and six to the Potsdam sandstone. The St. Peter wells and three of the Potsdam wells are connected by the tunnel system with the suctions of the centrifugal pumps at the bottom of the shafts. The other three

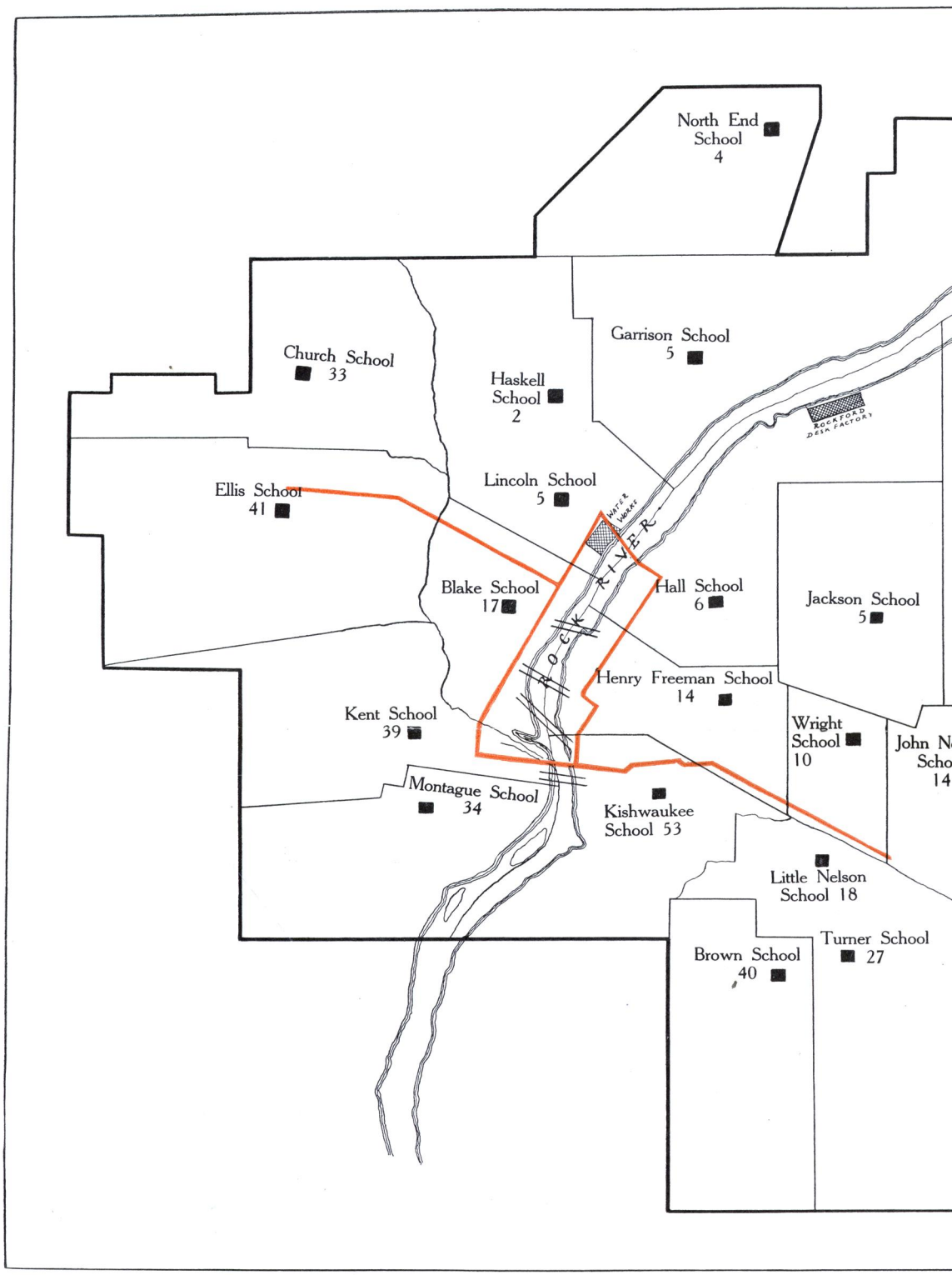
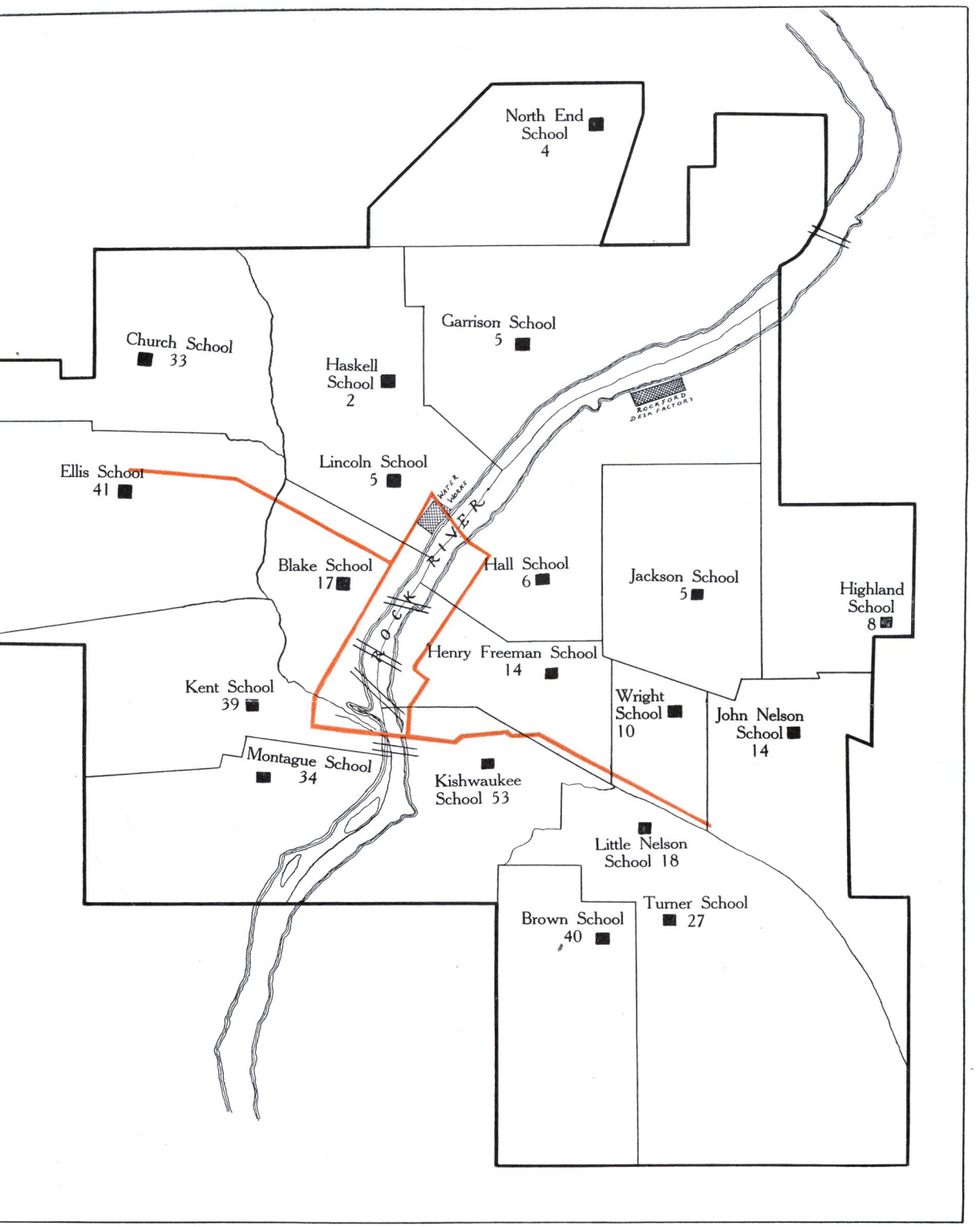
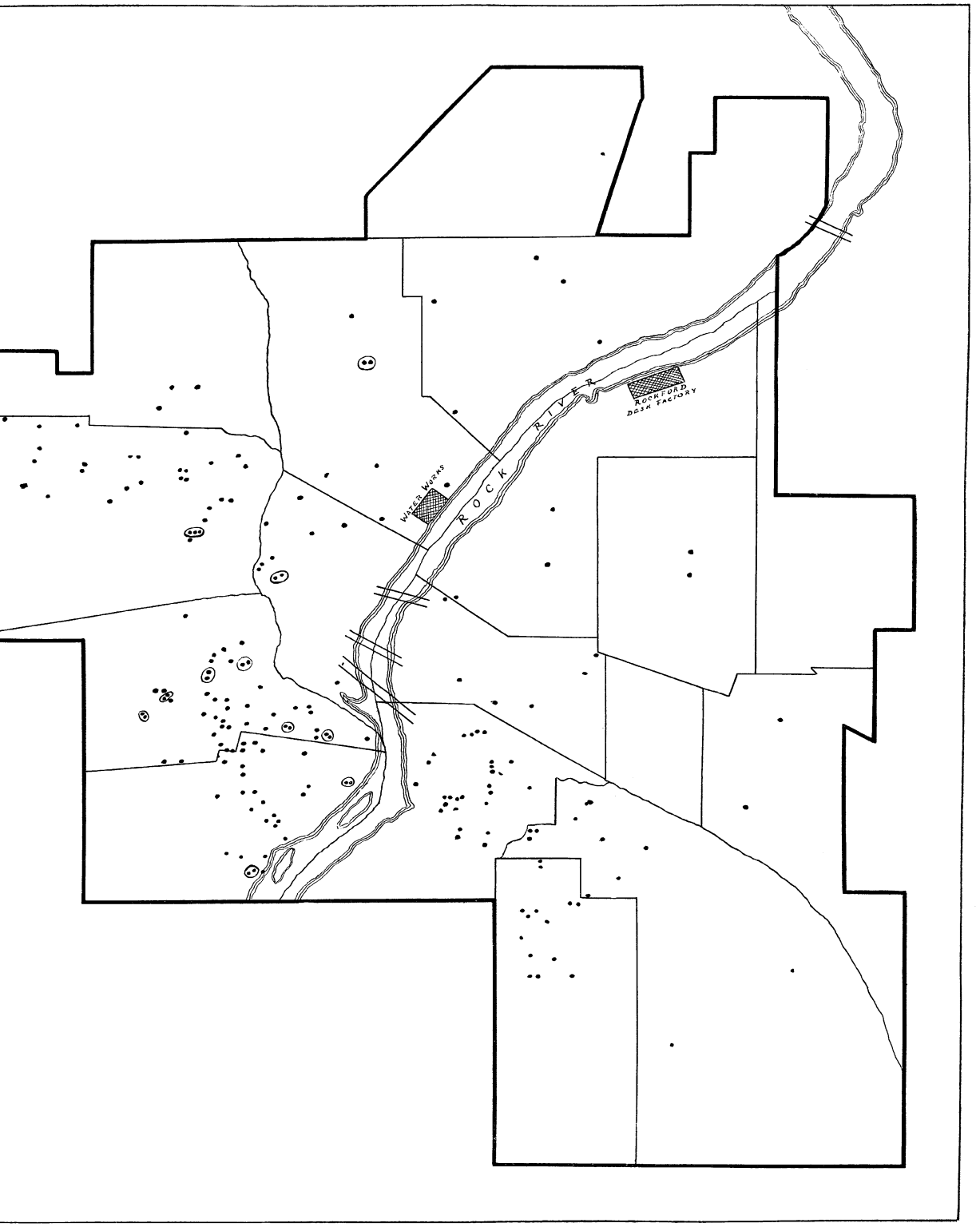


FIG. 2.—The figures show the percentage of children in each school who suffered from enteritis. The red lines represent the chief water ma
is south from the pumping station along the west bank of Rock River (factory district). The land is high to the north and east of the pumpin
correspondingly poor.



es show the percentage of children in each school who suffered from enteritis. The red lines represent the chief water mains. The main draught of water ing station along the west bank of Rock River (factory district). The land is high to the north and east of the pumping station and the water pressure



3.—Spot map showing distribution of typhoid cases in Rockford epidemic. Note correspondence with distribution of enteritis cases (Fig. 2).

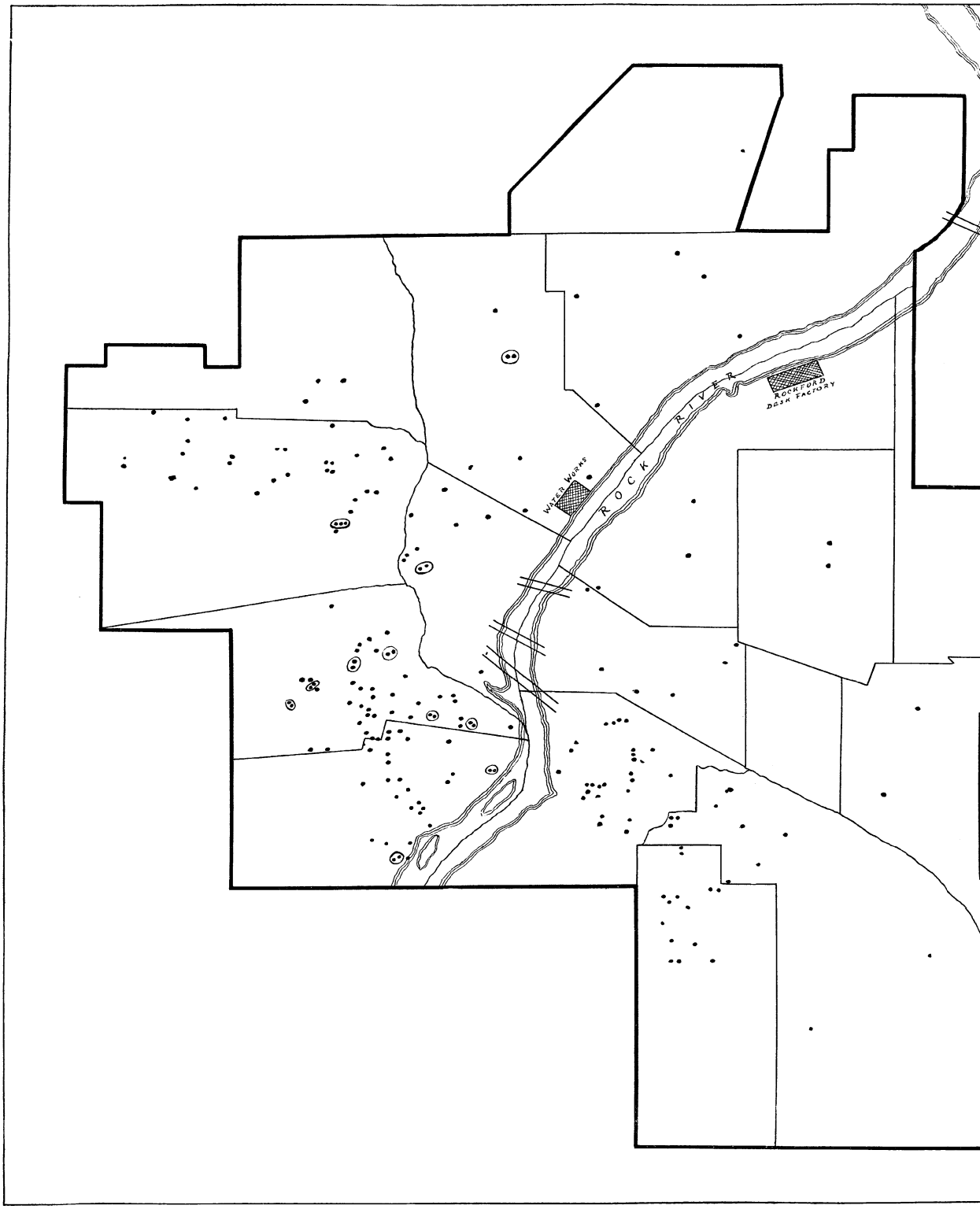


FIG. 3.—Spot map showing distribution of typhoid cases in Rockford epidemic. Note correspondence with distribution of enteritis cases (Fig. 2).

Potsdam wells (Nos. 2, 3, and 5) are not joined to the tunnel system, but are connected with a common discharge main through which the water flows by gravity to the pumping station (Fig. 1).

In 1892–93 a concrete storage reservoir of about 1,250,000 gallons capacity was constructed about 80 feet southwest of the pumping station. The reservoir is filled during hours of minimum pumping and drawn upon when the draft is heavier than the wells can supply. Ordinarily the draft upon the reservoir begins about 7 A.M. when the factories open, and continues till two or three o'clock in the afternoon, at which time the reservoir begins to be replenished. Under usual conditions about 200,000 to 300,000 gallons are drawn from the reservoir each day between 7 A.M. and 2 P.M. and a corresponding amount restored to it before the following morning. This supply is entirely inadequate and methods of extension are being considered.

From this brief description it is evident that the Rockford waterworks is not thoroughly adapted to the present use. Originally planned to furnish spring water, it has with relatively slight changes been used to distribute river water and again later artesian well water.

Examination of the present conditions showed several dangerous possibilities. At the time of the enteritis outbreak it seems to have been at first generally believed in Rockford that river water had been turned into the mains through the pipe connecting the upper portion of the older filter well with the river. On Monday night, January 15–16, there had been a large fire at the Rockford Desk Factory (Fig. 2) and a consequent heavy draft on the water system. A number of years ago it was the custom to admit river water to the mains for fire service, but this does not appear to have been done in any instances in recent years. All waterworks officials, including responsible engineers and assistants at the pumping station, denied the use of river water at the time in question. Three days after the fire one observer (see *Morning Star*, January 20) noted that the box near the old filter well containing the wheel and rod for the river valve was covered with snow and ice and showed no signs of having been disturbed for a long period (Fig. 4). Besides such direct evidence against the admission

of river water it may be pointed out that the distribution of the enteritis and typhoid fever cases was not what would have been expected had there been a rush of contaminated river water through the mains toward that section of the city where the fire was in progress. On the contrary, the northeast section of Rockford where the fire occurred suffered less severely than some other sections (see Figs. 2 and 3).

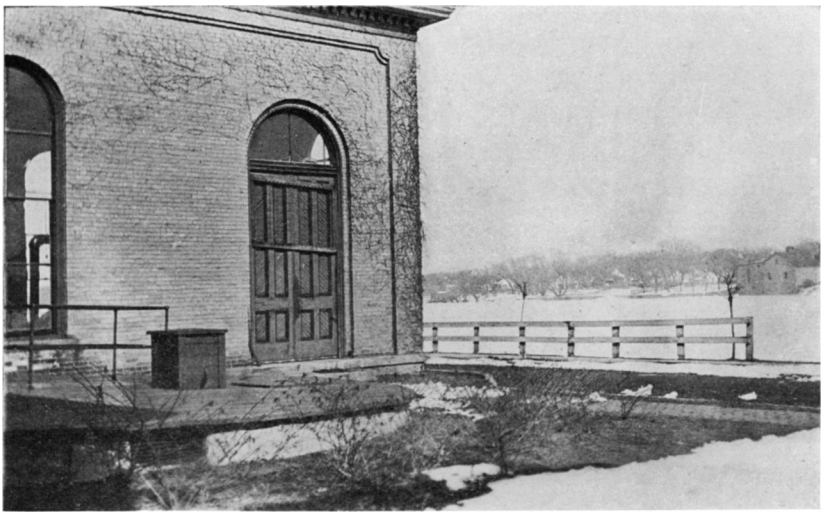


FIG. 4.—Southeast corner of pumping station, showing location of old filter well and valve location. Rock River east of station.

In addition to the pipe between the river and the main at the pumping station, there are some other river water pipes in connection with the fire protection systems at various factories along the river bank. Visits were made to a number of these factories and information obtained regarding the number of employees, number of enteritis cases, and other data. No record could be found of any fire in these factories on or about January 16 and there was no evidence of any sort, either in the distribution of cases or in the specific factory conditions, that river water had been admitted into the mains from this source. Samples of city water obtained by us from taps in various parts of the factory district showed no evidence of contamination.

Since everything pointed to some unusual occurrence at the time of or shortly following the Desk Factory fire which gave rise to an unusual infection of the public water supply, the whole water system was subjected to careful inspection. Three undoubtedly dangerous conditions were brought to light in the course of our inquiry. These may be considered separately.

1. *Peach Street well No. 2.*—This is one of the Potsdam wells lying southwest of the reservoir (Fig. 1). It was sunk in 1886 and is 1,320 feet in depth. The water from the deep well is raised by an air lift pump out of the well tube where it strikes a cast iron umbrella and drops back into a pit about eight feet deep which opens by a manhole to the street. The bottom of the pit is about 13 feet below the street level. When the well is being used the water flows by gravity from this pit to the suction well, by means of an overflow pipe placed about two feet from the bottom. At the time of our inspection of the pit, holes in the cover of the manhole permitted free access of street drainage to the pit. The pit was nearly full of water at the time of our inspection. Besides allowing entrance of surface water, the walls of the pit are not impervious and allow water from the surrounding soil to enter. A brick was noticed to be missing from the pit wall at one point. It is thus apparent that whatever the condition of the water from well No. 2 when drawn from the depths, it becomes mixed with the contaminated water of the pit before passing to the pumping station. In point of fact all samples collected from the trough running from this pit to the pumps have shown marked bacterial contamination, as indicated by a colony count averaging several thousand and the presence of *B. coli* in all 1 c.c. samples.

Whether the use of water from this contaminated well pit had anything to do with the explosive outbreak of January 16 may perhaps be determined by consideration of the following facts: The water from well No. 2 was allowed to run into the pumping pit on only one date between the summer of 1911 and the end of January, 1912. That date was Tuesday, January 16. On that day, according to the records at the pumping station, the air compressor in well No. 2 was operated from 11:45 A.M. to 10 P.M. Reference to the dates of enteritis attacks given above will show that

the date of onset of the earliest cases was the evening and night of January 16. This corresponds exactly with what would be expected if the explosion of enteritis and the subsequent outbreak of typhoid fever were due to the introduction on January 16 of the undoubtedly contaminated water of well No. 2 into the water system.

A further significant occurrence at this time was the filling of the storage reservoir which had been depleted to an unusual extent by the demand for water caused by the Desk Factory fire on January 15. During the hours when No. 2 well was being pumped, the reservoir water level was raised from seven feet to its usual height of about 18 feet; in all 804,600 gallons were pumped into the reservoir on January 16 as compared with 229,800 on January 15, and 251,550 on January 17. Since the reservoir is filled from the mains, part of the large volume of water entering the reservoir on January 16 must have been derived from well No. 2. This body of water was not completely removed from the reservoir for several days, the amount of water taken out of the reservoir and replaced by pure water daily being about 250,000 gallons, and it seems possible that contaminated water entered the mains from the reservoir for several days after the original infection had ceased. This may explain the dragging out of the enteritis cases over a number of days. It is not possible of course to determine how long the contamination persisted. Not only was the contaminated water diluted from day to day with the pure water, but there is reason to suppose that, as is usually the case under such circumstances, dangerous bacteria did not multiply, but died out more or less rapidly.

2. *The reservoir.*—As already stated, the capacity of the reservoir is only about one-third to one-fourth of the total daily supply. In times of heavy demand water is drawn from both the shaft system and reservoir; and in times of light demand, by means of a regulating valve at the old filter well, the water pumped by the shaft system in excess of the demand is stored in the reservoir. The bottom of the reservoir is below ground level and below the usual level of the river, 180 feet distant. On the north side of the reservoir the ground level is somewhat above the usual high water level in the reservoir (Fig. 5).

Ordinarily the height of water in the reservoir is said to range between 18.7 and 14.0 feet, but the level is not infrequently lowered considerably below 14 feet. Since the reservoir is partly below the ground level it became important to determine whether ground water could enter when the reservoir level is reduced to a degree reached in practical operation. On January 16, as already mentioned, the reservoir level was brought down to 6.6 feet.

FIG. 5.—Top of reservoir seen from north.

Examination of water samples taken by us from the reservoir when the level was over 14 feet had shown no evidence of contamination. When, however, the level was reduced to 6.6 feet on February 14 and kept there for about twelve hours, bacterial evidence of pollution was found. Inspection of the walls also showed some seepage. At one point along a small crack soft mud was found ridged out toward the interior of the reservoir. The same crack when examined immediately after the reservoir was emptied had shown no indication of inward seepage. The bacterial pollution was most marked on the north side of the baffle wall which runs at a height of about six feet longitudinally through the reservoir from east to west, separating the basins into north and south

divisions. The surroundings of the reservoir are not prepossessing (Figs. 5, 6, 7, and 8). Owing to the proximity of the sewage-polluted Rock River, whose level is sometimes above the bottom of the reservoir, to the nearness of the Peach Street sewer, and to other sources of contamination, the soil and ground water in the neighborhood of the reservoir and pumping station must, as a rule, contain dangerous impurities. One privy is in use within five feet of the north wall (Fig. 8). The reservoir levels on January 15 and 16 are recorded as follows:

January 15, 1912	7 A.M.	18′7″	
	9	16′7″	
	12 Noon	15′5″	
	3 P.M.	15′5″	
	4	15′7″	
	5	15′7″	
	6	15′5″	
	7	16′	
	8	16′6″	
	9	17′2″	
	10	17′9″	
	11	18′5″	Fire started at 11:45 P.M.
January 16, 1912	12 Midnight	18′6″	
	1 A.M.	17′3″	
	2	16′	
	3	15′2″	
	4	13′8″	
	5	12′4″	
	6	11′1″	
	7	8′7″	
	8	7′1″	
	9	6′6″	
	11:45 A.M.	....	Well No. 2 started into the pumping pit
	12 Noon	7′1″	
	2 P.M.	8′	
	3	8′9″	
	4	9′9″	
	5	10′8″	
	6	11′4″	
	7	12′6″	
	8	13′6″	
	9	14′9″	
	10	16′2″	Well No. 2 discontinued.
	11	17′4″	
	12 Midnight	18′7″	

On January 17 the lowest level reached was 16.0; January 18, 16.0; January 19, 15.6; January 20, 16.1; January 21, 13.9. The amount of water pumped into the reservoir during the eventful week is shown by meter readings as follows:

January	14, 243,600 gallons	January	18, 264,975 gallons
"	15, 229,600 "	"	19, 280,950 "
"	16, 804,600 "	"	20, 212,150 "
"	17, 251,550 "	"	21, 408,225 "

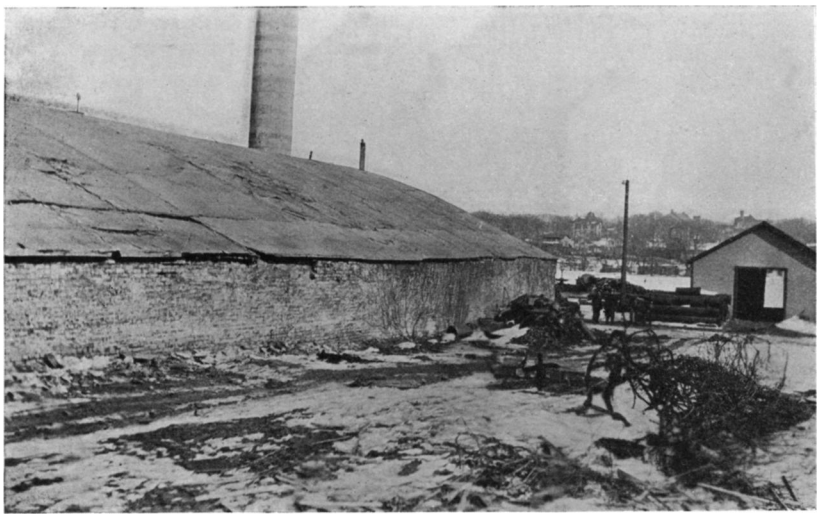


FIG. 6.—South wall of reservoir. + Shows location of privy just dismantled.

The gauge readings show that after the reservoir level had been lowered to 6.6 feet on the morning of January 16 no more water was drawn from the reservoir until after 9 A.M., January 17. Since there is abundant evidence that many cases of enteritis occurred in the night of January 16–17 contamination of the reservoir water by seepage may be dismissed as the first or sole cause of the outbreak. Whether or not it was a contributory or secondary factor must remain an open question. Some seepage may have taken place when the reservoir level was lowered to 6.6 feet on January 16, and this may have reinforced the contamination from other sources, but certainty on this point is plainly impossible. Examination of the reservoir when it was emptied for inspection on February

22 showed no extensive seepage, although some bacterial contamination on the north side was clearly apparent. On the whole it is our opinion that the reservoir, although dangerously placed and insufficiently protected, played a very minor part, if any at all, in the outbreak.

3. *The pumping pit and filter well.*—In the report on the enlargement of the Rockford water supply already referred to the

FIG. 7.—West end of reservoir on the right.

statement occurs: "We are informed that the bottom and sides of the suction well at the station freely admit the ground water whenever its level is higher than that of the water in the suction well." On further inquiry we found that it was generally admitted that both the suction well or pumping pit and the old filter well were pervious, and might under certain conditions permit entrance of the ground water. The use of these porous receptacles is plainly dangerous. The ground water in the neighborhood of the pumping station is highly contaminated. In addition to the numerous privies in use in the neighborhood, the whole sewerage system in this part of the city contributes to the pollution of the ground water. Sewers enter Rock River in the half-mile above the pump-

ing station at eight different points. The large Peach Street sewer empties into the river just below the pumping station (Fig. 1). Near the lower end of the city the river is dammed for power purposes, forming a pool about 10 feet in depth just above the dam. The crest of the dam has recently been raised about a foot, making the river level this year higher than before. At the waterworks the level of the river water is above the bottom of the pumping

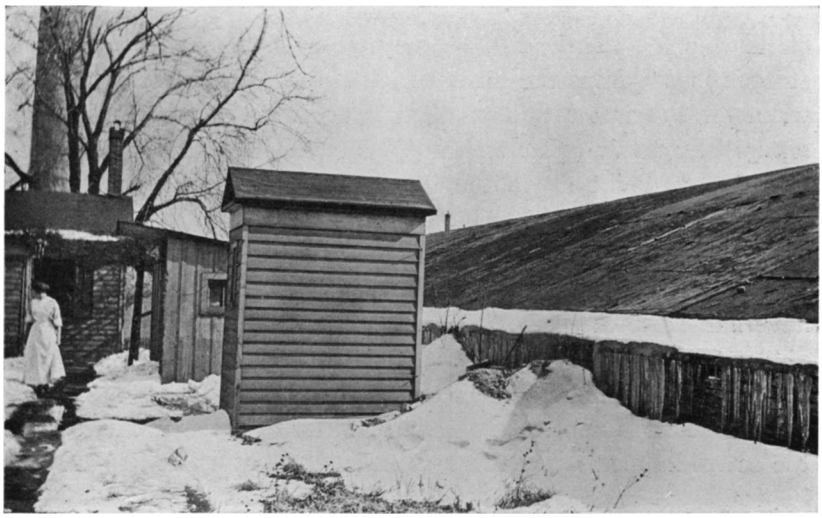


FIG. 8.—North side of reservoir, showing privy within five feet of wall.

pit and filter well a large part of the time, and sometimes above the level of the reservoir bottom. The distance from the filter well to the river is only about 40 feet. All these facts indicated a critical condition.

The level in the suction well usually ranges, according to the waterworks officials, from 10 to 12 feet, but is not uncommonly reduced to eight feet. In the event of a heavy draft because of a fire, the pumps are speeded up and the level of the water lowered in a very short time. Since the level and the degree of contamination of the ground water must undoubtedly vary, the particular level at which contamination would take place could in no case be predicted. That seepage of ground water into the suction well

might take place was shown first by analyses, second by emptying the pit. Repeated bacterial examination of the water in the suction well when the level was 10–12 feet showed no trace of pollution, the plates being sterile or containing only three or four colonies. When, however, the water was lowered to $8\frac{1}{2}$ feet, a level said to be not infrequently brought about by slight changes in the rates at which the pumps are operated, the number of bacteria in the surface water increased to about 50 (37° C.). Samples taken four feet below the surface showed 1,500 colonies per c.c. The porosity of the pits was manifest when they were later emptied. On first stopping the pumps the pit level fell about a foot overnight, and when all the water was pumped out *about six feet "of refined sewage" seeped in before morning.* City officials no longer entertained any doubt as to the danger from this source. As one official expressed it: "We have been sitting on a keg of powder with a sputtering pipe in our mouths. That the explosion was not greater and more harmful than it was passes comprehension. We have had an unexcelled water source and then handled it as they did several decades ago—put our water storage in the middle of a cesspool and trusted to chance that it would not be contaminated."

No record is kept of the level of water in the suction pit, and the actual happenings in this respect on January 15 and 16 are not known.

It is plainly impossible to apportion exact responsibility for the epidemic between well No. 2, the reservoir, and the suction well. It may be pointed out that besides fluctuation in water level in the different receptacles for the deep well water, two other variable factors are concerned, namely, the level of the ground water and the degree of contamination of the ground water. Neither of these latter factors can be predicted or controlled with any degree of certainty. A given water level in any of the pervious underground receptacles of the water may at one time be sufficient to keep out ground water altogether, while at another it may allow seepage to enter. It is not possible, therefore, to assume that the condition of water collected at one time necessarily corresponds precisely with the condition of the water at an earlier period, even if the level within the receptacle were known to be the same. Unknown

and uncontrollable changes in the ground water are just as likely to bring about contamination under suitable conditions as changes in the level of the container.

The facts as set forth might be thought to indicate that before the present extensive outbreak occasional pollution had occurred from one or more of the sources previously considered, but it is plainly impossible to obtain proof of this view. In the spring of 1910 well No. 2 was fitted with a Norris nozzle and the engineer's report already cited states that "Owing to the obstruction in the casing of well No. 2, the Norris nozzle is said to have stuck at about 140 feet below the surface and attempts to lower it beyond this depth failed." It is uncertain whether there is any causal connection between this occurrence and the increased prevalence of typhoid fever since the spring of 1910. Water samples obtained directly from well No. 2, without admixture with the water of the pit, have given some evidence of contamination, but it has not been possible to obtain samples under entirely satisfactory conditions. The question needs further examination by local authorities before the well is again used.

The distribution of the enteritis cases throughout the school population is sufficiently peculiar to call for explanation (Fig. 2). The distribution of typhoid fever cases follows the enteritis distribution very closely (Fig. 3). It will be noted first that the whole northern section of the city is less severely affected than the southern and western sections; second that the region in which the furniture factory fire occurred on January 16 is among the slightly affected districts. The cause for this uneven distribution of the contaminated water is probably the relatively short time during which the extreme pollution continued, coupled with the greater demand for water made throughout the daytime by the factory and business districts. As already stated, the demand for water by the factories is greatest during the forenoon and early afternoon. On the morning of January 16 the increased demand for water was faced by an empty reservoir. The emergency was met by speeding up the pumps, this in turn drawing contaminated ground water into the suction well. This polluted water went where the draft was at the time greatest, namely, into the southern and western

districts, while the northern residential district, largely on high ground where the water pressure is at best low, received relatively little of the temporarily contaminated water. The contaminated water from well No. 2 also entered the system about noon at a time when the water demand from the southern section of the city was still high. On the following days whatever contamination might exist in the reservoir was distributed to the same section of the city.

The distribution of cases, somewhat unusual for a water-borne epidemic, is thus seen to depend upon (*a*) the temporary nature of the contamination of the water, and (*b*) the fact that at the time the contamination occurred the draft of water in certain districts was much heavier than in others. Those districts where the water demand was large throughout the daytime on January 16 were the ones that had a relatively large share of enteritis and typhoid fever cases.

The obvious recommendations were made. The use of well No. 2 was discontinued. Hypochlorite of lime was added to the reservoir and the reservoir used as a pumping pit while the suction pit at the pumping station and the old filter well were being made impervious to ground water. The usual precautions against infection of milk supplies were taken, and special measures for preventing later fly infection and contact infection were carried out by the health commissioner, Dr. W. E. Park. Abolition of privies and shallow wells was urged on the ground of possible future infection.

SUMMARY.

The Rockford outbreaks of enteritis (10,000 cases) in January, and of typhoid fever (199 cases) in February, 1912, were due to an unusual contamination of the public water supply occurring on January 16, 1912. The city supply was derived at the time of the outbreak entirely from deep wells. The deep well water, as it is drawn to the surface, is of unimpeachable quality, but the nature of the receptacles in which it is placed prior to distribution exposes it to pollution. These receptacles are porous pits located in a region where the ground water is highly charged with sewage. It

has been proved that the polluted ground water is able to enter these pits under conditions similar to those known to have obtained on January 16, a date when the demand upon the water system was unusually great, owing to a large factory fire. On the same date (January 16) a long-unused well was drawn upon as a source of supply. We have shown that the construction of this well and its mode of connection with the pumping station expose the water to contamination before it enters the general system. Under certain conditions of the ground water level this contamination, owing to the proximity of a large sewer, may be very gross. Since inspection and analysis have shown that both these sources of contamination exist and were undoubtedly operative under conditions prevailing on January 16, it is impossible to assign to either factor the sole or even the major responsibility for the outbreak. Possibly both were reinforced by a third factor, a slightly leaky reservoir drawn upon after the outbreak was under way, but this is uncertain.

We are under special obligation to his Honor, W. W. Bennett, mayor of Rockford, and Dr. Wm. E. Park, commissioner of health, for much assistance rendered us in the course of our investigation.